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A CASE OF ABNORMALITY IN CATS' PAWS.

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THIS paper contains an account of facts learned by the study of the walking pads, the muscular, vascular, nervous, and skeletal systems of the manus of a polydactyle and syndactyle cat. The cat furnishing the material for this study was one of a strain of polydactyle cats living in Cambridge, Massachusetts, and descended from a polydactyle cat which lived at the astronomical observatory of Harvard University. All four legs of the cat dissected were preserved in alcohol and were kindly given me for study by Dr. C. B. Davenport, under whose direction the work was done. To him and to Prof. E. L. Mark I wish to extend my thanks for kind advice and criticism.

Each fore paw had six toes; the toes of the hind paws were fused in pairs almost to the ends of the claws, as is shown in Figs. 1 and 2.

The syndactyle hind paws have not been dissected, but a drawing of the palmar and dorsal surfaces is shown in Figs. 1 and 2 respectively. Walking pads and distal phalanges both indicate that the four digits are fused in pairs.

I wished to determine, if possible, which toe of each fore paw is the extra one, and what is the nature of the evidence.

I have been unable to learn of any account of a study on material precisely similar to this. The collection of facts in Bateson's "Materials for the Study of Variation" covers the ground worked over by previous authors, and this, with Poulton's papers, includes an account of all the published facts on the subject, as far as known to me. Previous study has been only on the walking pads and on the skeleton. Bateson described principally skeletal structures, and Poulton studied the walking pads. They have drawn their conclusions as to the true nature of polydactylism from facts learned from these two organs only. It is, of course, desirable to have as complete a knowledge as possible of the anatomy of the paw, as a basis for any conclusions to be drawn. I find from my dissections that the evidence furnished by the walking pads and skeletal system is borne out by the other organs mentioned.

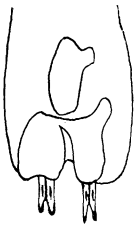

FIG. 1.

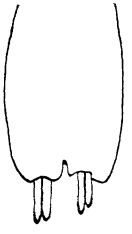

FIG. 2.

FIG. 1. — Palmar aspect of hind paw of abnormal cat, showing fused pads.

FIG. 2. — Dorsal aspect of hind paw of abnormal cat, showing claws fused in pairs.

The general appearance of the polydactyle paw studied, apart from the increased number of digits, is quite different from that of a normal fore paw. The radial digit in the polydactyle paw extended much nearer to the end of the paw than the pollex normally does, the digits being more nearly of the same length than in the normal paw. A comparison of the relative positions of the ungual and middle phalanges during the retraction of the former will be made when we come to the study of the bones.

The walking pads of the polydactyle paw (Fig. 4) differ from those of the normal paw (Fig. 3) in that the phalango-metacarpal

pad (*pulv.phlx-mt'carp.*) of the polydactyle is five-lobed instead of three-lobed as normally, and the lobes in the polydactyle paw are more clearly marked off from one another than in the normal paw. The parts of the five-lobed pad which appear to correspond to the phalango-metacarpal pad of the normal paw are the three external lobes which are more closely associated with one another than with the two internal lobes; while the two internal lobes are more closely applied to each other than to the three external ones. That

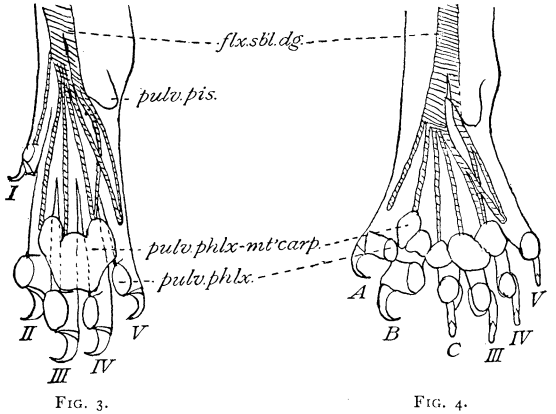

FIG. 3.

FIG. 4.

FIG. 3. — Palmar aspect of right fore paw of normal cat.

FIG. 4. — Palmar aspect of right fore paw of polydactyle cat. *A*, radial digit; *B*, second digit, etc.; *I*, pollex; *II*, index; *III*, medius; *IV*, annulus; *V*, minimus; *flx.sbl.dg.*, flexor sublimis digitorum; *pulv.phlx.*, phalangal pads; *pulv.phlx.-mt'carp.*, phalango-metacarpal pad; *pulv.pis.*, pisiform pad.

five lobes instead of three existed in the polydactyle paw is probably due to the fact that one lobe was added by the formation of an extra digit, and that the growth of the radial digit, which occurred to so unusual an extent that it functioned more like a walking digit than the pollex normally does, excited the growth of a phalango-metacarpal pad on this digit also. In both the normal and the polydactyle paw there is a walking pad on the distal end of each middle phalanx (*pulv.phlx.*) and on the pisiform bone (*pulv.pis.*).

MUSCLES.

As in the normal fore paw, the muscles *extensor carpi radialis longior* and *extensor carpi radialis brevior* (Figs. 5, 6, *ext.carp.r.lg.* and *ext.carp.r.brv.*) are inserted on the proximal dorsal surface of the second and third (counting from the radial side) metacarpal bones respectively.

Considering the evidence of these two muscles alone, we should infer that in the polydactyle paw the radial side is normally formed and that the extra digit is external to (on the

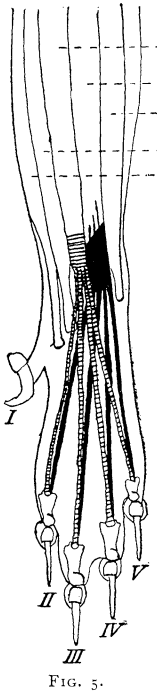

FIG. 5.

FIG. 6.

FIG. 5.—Dorsal aspect of left manus of normal cat, showing dissection of muscles. *ext.carp.r. brv.*, extensor carpi radialis brevior; *ext.carp.r.lg.*, extensor carpi radialis longior; *ext.carp.uln.*, extensor carpi ulnaris; *ext.com.dg.*, extensor communis digitorum; *ext. min.dg.*, extensor minimi digiti.

FIG. 6.—Dorsal aspect of left manus of polydactyle cat, showing dissections of same muscles as in Fig. 5.

ulnar side of) the third one, for in the polydactyle paw there are three digits external to the insertion of the *extensor carpi radialis brevior*, whereas in the normal paw there are only

two. Such an inference, however, is not borne out by the evidence of other muscles and tissues.

Muscles *extensor communis digitorum* and *extensor minimi digiti* (Figs. 5, 6, *ext.com.dg.* and *ext.min.dg.*) in both normal

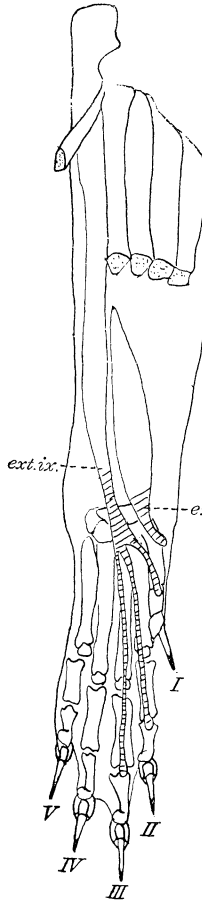

FIG. 7.

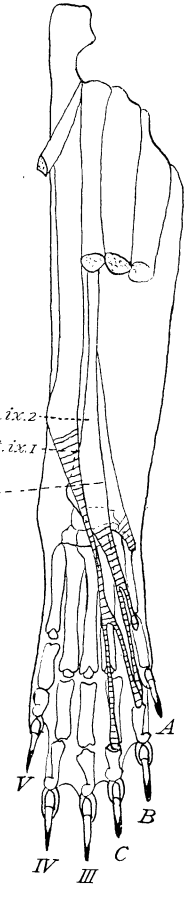

FIG. 8.

FIG. 7. — Dorsal aspect of right manus of normal cat, showing dissection of deep muscles. *ext.ix.*, extensor indicis; *ext.mt'carp. poll.*, extensor metacarpi pollicis.

FIG. 8. — Dorsal aspect of right manus of polydactyle cat, showing same deep muscles as in Fig. 7. (See text for description of *ext.ix.1* and *ext.ix.2*.)

and polydactyle paw extend to the proximal dorsal surface of the middle phalanx of each of the four external digits. The distribution of these muscles points to the inference that the

four external digits of the polydactyle paw correspond to the external four in the normal cat, and that the extra digit occurs on the radial side of the four external digits, an inference which, with some modifications, seems to be confirmed by other facts.

Muscle *extensor carpi ulnaris* (Figs. 5, 6, *ext.carp.uln.*) in both normal and polydactyle paw is inserted on the ulnar metacarpal.

The *indicator* (Fig. 7, *ext.ix.*) is somewhat variable in respect to its insertion, even in normal specimens, sometimes supplying the pollex, index, and medius, sometimes only the pollex and index. In the polydactyle paw a peculiar arrangement exists, in that there are two muscles in place of one. That which, from relative position and insertion, seems to correspond to the normal one (Fig. 8, *ext.ix.1*) is distributed to the second (*B*) and third (*C*) digits.

In addition to this muscle there is under it, and distinct from it, another muscle (*ext.ix.2*), which passes in the same general direction to the two internal digits (*A* and *B*, Fig. 8). This muscle has a more distal origin than does the one supplying digits *B* and *C*; it originates from the dorsal border of the ulna and passes directly over the muscle *extensor metacarpi pollicis* (*ext.mt'carp.poll.*). Comparisons of the two indicators with each other and with the normal muscle seem to point to a readjustment to meet a new condition of the manus.

In both the normal and the polydactyle manus the radial metacarpal furnishes insertion for the *extensor metacarpi pollicis* (Figs. 7, 8, *ext.mt'carp.poll.*).

Muscle *flexor carpi radialis* in both the normal and the polydactyle paw has its tendons inserted on the proximal ends of the palmar surface of the second (counting from the radial side) metacarpal.

The ulnar part of the *flexor sublimis digitorum* in both normal and polydactyle paws has tendons extending to the first and second digits, counting from the *ulnar* side (Figs. 3, 4, *flx.sb'l.dg.*), while the tendons from the radial part of the muscle extend in the normal paw to the four, and in the polydactyle paw to the five, digits nearest to the radial side.

The fact that in the polydactyle paw the union between the tendons to the digits marked *IV* and *V* (Fig. 4) extends further distally than in the normal paw (Fig. 3) is apparently less important than the fact that in the polydactyle paw the radial part of the muscle has five tendons while the normal paw has only four.

Muscle *flexor profundus digitorum* (Figs. 9, 10, *flx.profnd.dg.*) has in the normal paw five, and in the hexadactyle paw six,

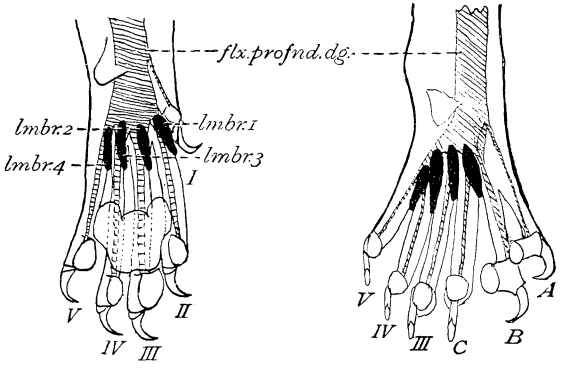

FIG. 9. FIG. 10.

FIG. 9. — Palmar aspect of left manus of normal cat, showing dissection of deep muscles.

FIG. 10. — Palmar aspect of left manus of polydactyle cat, showing muscles as in Fig. 9. *A*, radial digit of polydactyle manus; *I*, that of normal manus; *flx.profnd.dg.*, flexor profundus digitorum; *lmbr.1–4*, lumbricales 1–4.

tendons distributed one to each digit. There is no evidence here as to which digit is the extra one.

Muscle *flexor carpi ulnaris* is inserted on the pisiform bone in both normal and polydactyle paws.

There are four *lumbricales* in both normal and polydactyle paws (Figs. 9, 10, *lmbr. 1–4*). In both cases these are inserted one each on the radial side of the proximal phalanx of each of the four external digits. In the polydactyle paw there is no lumbrical superficial to the radial border of the distal part of the *flexor profundus digitorum*.

BLOOD VESSELS.

The arrangement of the veins on the dorsal surface of the normal and the polydactyle fore paw is shown in Figs. 11 and 12. The only points that can be taken as homologous for determining the corresponding veins in the normal and polydactyle paw are the most distal point of the loop formed by the anastomosis of the ulnar (*v.uln.*) with the radial (*v.r.*) vein. This point in both normal and polydactyle paws seems to be between digits marked *III* and *IV*. Starting from this point, we see that in the normal paw there are three branches, and in the polydactyle paw four branches, which contribute to the radial vein. These facts suggest the conclusion that the extra digit of the polydactyle paw is on the radial side; but owing to the uncertainty of the exact position of this point of reference, the evidence from the veins is of less value than that from some of the other organs.

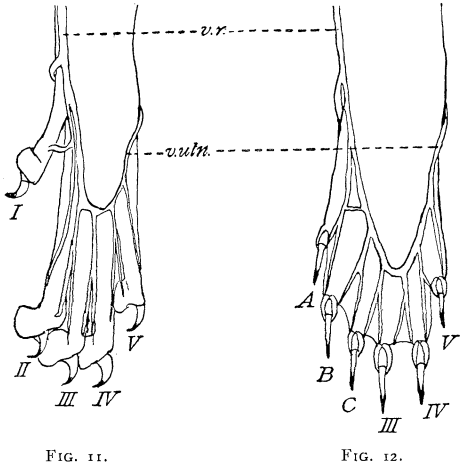

FIG. 11. FIG. 12.

FIG. 11. — Dorsal aspect of left manus of normal cat, showing arrangement of veins. *v.uln.*, ulnar vein; *v.r.*, radial vein.

FIG. 12. — Dorsal aspect of left manus of polydactyle cat, showing arrangement of veins.

In studying the arteries the only fact which throws any light on the problem is the relative size of the digital branches from the *palmar arch* (Figs. 13, 14). The branch which supplies the radial digit is small in both the normal and the polydactyle paw. In the normal paw the branch to the index is as large as the branches to each of the other three digits; but in the polydactyle paw the branches to digits $A + B$ and $B + C$ (Fig. 14), while about equal to each other in size, are much smaller than those to the external digits.

Nerves

The *radial nerve* after becoming subcutaneous follows the course and distribution of the dorsal veins, which are shown in Figs. 11 and 12. The *median nerve* (Figs. 15, 16, *n.m.*) besides supplying the muscle *flexor communis digitorum* is distributed to *four* consecutive digits, beginning with the radial side, in the normal and to *five* consecutive digits in the polydactyle paw. In the normal manus the *ulnar nerve* divides, just below the olecranon, into an inner (ventral, *n.uln.v.*) and an outer (dorsal, *n.uln.d.*) branch (Fig. 15). The outer (dorsal) branch passes to the outer side of digit *V* and also sends dorsally a branch to the internal side of the same digit and to the external side of digit *IV*. In both normal and polydactyle manus the internal (ventral) branch of the ulnar (Figs. 15, 16, *n.uln.v.*) supplies the three external digits.

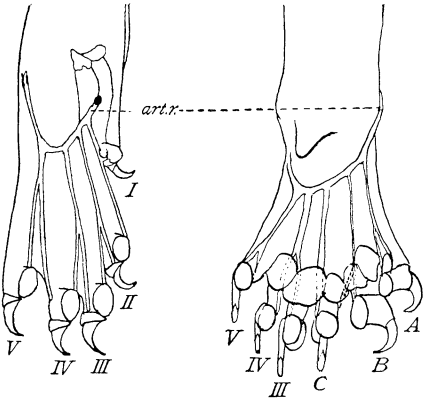

Fig. 13. Fig. 14.

Fig. 13. — Palmar aspect of left manus of normal cat. *art.r.*, radial artery.

Fig. 14. — Palmar aspect of left manus of polydactyle cat.

For a point of reference in comparing the nerves we may take a small branch which passes from the *ulnar* to the *median* nerve. This unites with that branch of the median which in the normal manus (Fig. 15) passes to the ulnar side of digit *III* and to the radial side of digit *IV*. *In the hexadactyle manus (Fig. 16) the branch of the median nerve which is joined by the ulnar nerve likewise passes to the ulnar side of digit III and to the radial side of digit IV.* There is, then, in the abnormal manus radially to the nerve of reference one more digit than exists in the normal manus. This makes it apparent that the modification producing polydactylism has occurred on the radial side of the manus.

SKELETON.

The ulnar, radial, and carpal bones are practically the same in number, relative size, shape, proportion, etc., in the normal and abnormal manus. There are in the polydactyle paw six *metacarpals*, a pollex of two phalanges, and five digits, each with three phalanges. All the bones of the normal paw (Fig. 17) are larger and stouter than those of the polydactyle paw (Fig. 18). Bones of a normal paw were prepared for the purpose of making comparisons with the abnormal skeleton in respect to weight, relative proportions, etc. In making these comparisons, allowances are made for the general differences mentioned above.

The *radial sesamoid* of the *carpus* of the six-toed cat (*ses.*, Fig. 18) is fused to the radial side of the scapho-lunar (*scph-lun.*) and furnishes the place of articulation for the metacarpal of the pollex. In the polydactyle manus the four external metacarpals (*mt'carp.*) have the same articulations with the distal row of carpals as in the normal manus. In the normal manus the *pollex* articulates with the *trapezium* (*trz.*), while in the abnormal manus (Fig. 18) the metacarpal of digit *B* articulates with the trapezium. Metacarpal of digit *A* (Fig. 18) articulates, as previously stated, with the radial sesamoid (*ses.*), which is fused to the scapho-lunar (*scph-lun.*).

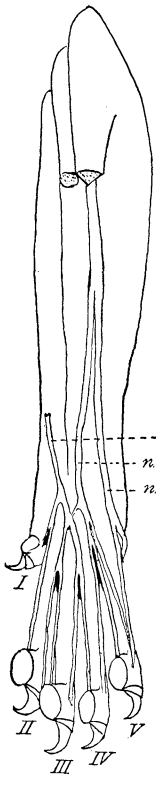

FIG. 15.

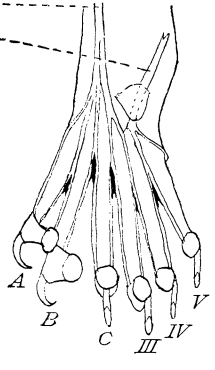

FIG. 16.

FIG. 15. — Palmar aspect of right manus of normal cat. *n.m.*, median nerve; *n.uln.d.*, dorsal branch of ulnar nerve; *n.uln.v.*, ventral branch of ulnar nerve.

FIG. 16. — Palmar aspect of right manus of polydactyle cat.

The metacarpal bones in both manus are similar, except that there is in the abnormal manus no "groove" for the radial

artery. The metacarpals, as well as the other bones of the pollices, vary considerably in length and thickness, and in this respect will be considered more closely later.

There is no particularly noticeable variation in the proximal series of phalanges (*phlx.prx.*). These bones have the least distinctive characters, differing from one another chiefly in size.

The series of middle phalanges (*phlx. m.*) furnishes very interesting conditions. In both the normal and abnormal manus the three external (ulnar) middle phalanges are carved away on the ulnar side to allow for the retraction of the corresponding ungual phalanges (*phlx.ung.*). The middle phalanx of the index of the normal manus is likewise carved away on the ulnar side, but in the abnormal manus the digit (*C*, Fig. 18) next to the three ulnar digits is carved away on neither side and is therefore "indifferent." The middle phalanx of digit *B* (Fig. 18) has no counterpart in the normal

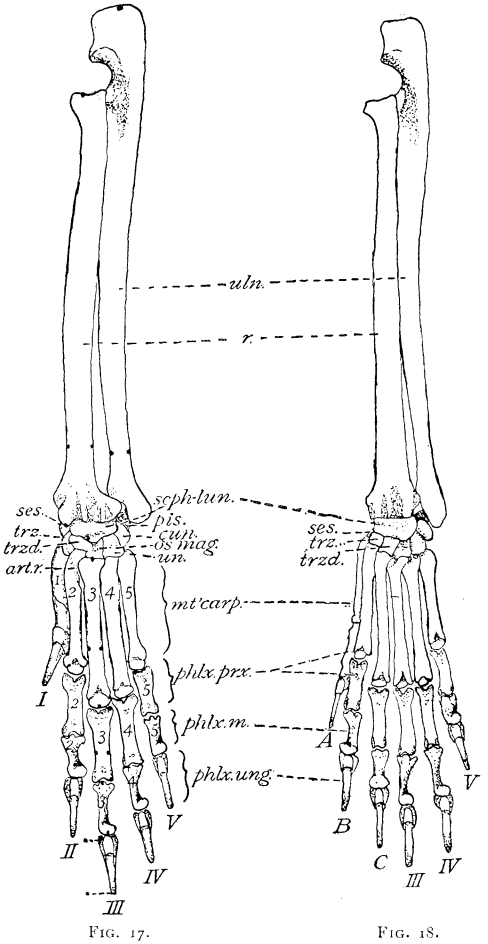

FIG. 17. FIG. 18.

FIG. 17. — Dorsal aspect of skeleton of left manus of normal cat.

FIG. 18. — Dorsal aspect of left manus of hexadactyle cat. *A*, radial digit of abnormal manus; *I*, that of normal manus; *art.r.*, groove for radial artery; *cun.*, cuneiform; *mt'carp.*, metacarpals; *un.*, uncinate; *os mag.*, os magnum; *phlx.m.*, middle phalanges; *phlx.prx.*, proximal phalanges; *phlx.ung.*, ungual phalanges; *pis.*, pisiform; *r.*, radius; *scph-lun.*, scapho-lunar; *ses.*, sesamoid; *trz.*, trapezium; *trzd.*, trapezoid; *uln.*, ulna.

manus, except that it is somewhat like a pollex, which, when retractable, as occasionally happens, is carved away on the radial side.

The ungual phalanges are too nearly alike in the normal and the polydactyle paw to be of service as far as our purpose is concerned.

GENERAL CONSIDERATIONS.

The facts learned from the dissection of the polydactyle manus are in part contradictory; that is, some facts suggest that the extra digit occurs on the radial side of the paw, whereas others indicate an extra digit on the ulnar side; but, on the whole, the balance of the evidence points to the existence of the extra digit on the radial side of the three ulnar digits. The evidence which the bones furnish seems to be the most satisfactory, and is borne out in the majority of cases by the other tissues. The middle phalanges of digits *III*, *IV*, and *V* (Figs. 17, 18) are carved away on the ulnar side, as normally. The middle phalanx of digit *C* (Fig. 18) is an indifferent digit, *i.e.*, carved away on neither side. In this it more resembles a pollex than a digit. The middle phalanx of digit *B* (Fig. 18) is carved away on the radial side, in this respect resembling a pollex more than a digit. Digits *III*, *IV*, and *V* in both manus are distinctly similar. Regarding the articulation of the metacarpals with the carpals, it is seen that the five external digits of the abnormal manus have the same articulation as do the five digits of the normal manus. The pollex of the abnormal manus has the articulation abnormal, in that it is with the radial sesamoid, which in this case is fused with the scapho-lunar. Here the five digits nearest the ulnar side are normal.

Considering the three ulnar digits of the abnormal manus to correspond to normal digits, one is naturally led to inquire what modifications the manus has undergone that there should be three digits instead of two on the radial side of the three ulnar normal ones. Further evidence from the bones is interesting in respect to this query.

A comparison of the indices and the weights of the individual bones of both the normal and abnormal manus is shown in the accompanying table. For the purpose of more accurate comparison of the two sets of bones, I have figured the percentage which each bone bears to the total weight of all the bones of the manus to which it belongs (including ulna and radius). The indices of the bones were obtained by finding the ratio between the minimum thickness and the maximum length of each bone. The actual points of measurement are shown by the dots in Fig. 17, *III.* Inspection of the bones first leads us to see that digit *A* (Fig. 18) is much longer than the normal pollex and presents in the undissected manus more the character of a finger than of a pollex. The bones, however, are distinctly those of a pollex, since there are two phalanges only; but they are longer and more slender. In this respect they resemble a finger. The bones of digit *B* (Fig. 18) are more like a pollex than are those of the digit which normally adjoins the pollex. One can also see that digit *C* (Fig. 18) is more like a pollex than is the digit which is normally fourth from the ulnar side. What further facts are there to bear out the idea that where there are normally two digits, there abnormally occur three, each of which partakes somewhat of the general characters of the others?

It is a fact that where normally two digits are found, namely, a pollex and an index, there are found in this special case three, and that the material which would normally form two digits has so distributed itself that each of the three digits which actually occurs partakes of the nature of the other two. Is the abnormal pollex two-thirds pollex and one-third index; the digit next the pollex, one-half index and one-half pollex; and the digit *C* (Fig. 18) two-thirds index and one-third pollex? There seems to be some relation of this sort.

If we compare the indices and the relative weights of the two manus, we come to a like conclusion (see accompanying table). For example, comparing the percentages of total *weights* in the abnormal manus, metacarpal *A* (Fig. 18) is more like the other metacarpals of its manus than is metacarpal *I* of the normal manus like the other metacarpals of its manus;

NORMAL.

	GRAMS WEIGHT.	PERCENTAGE WEIGHT.	MILLIMETERS MEASUREMENT.	PERCENTAGE INDEX.
Ulna	3.467	.333	45 × 1030	.0437
Radius	2.679	.257	52 × 878	.0592
Carpals	.699	.067	—	—
Metacarpals				
I	.135	.012	32 × 112	.286
II	.423	.040	28 × 284	.0986
III	.525	.054	32 × 321	.0997
IV	.445	.043	30 × 300	.100
V	.348	.033	28 × 247	.113
Totals of metacarpals	1.876	.182	—	—
Proximal phalanges				
I	.096	.0092	32 × 82	.402
II	.157	.0158	32 × 136	.235
III	.188	.0187	33 × 155	.203
IV	.161	.0154	30 × 147	.204
V	.127	.0122	29 × 118	.245
Totals of proximal phalanges	.729	.0713	—	—
Middle phalanges				
I	—	—	—	—
II	.097	.0093	23 × 94	.244
III	.108	.0103	23 × 115	.200
IV	.094	.0090	23 × 108	.213
V	.078	.0075	28 × 82	.341
Totals of middle phalanges	.377	.0361	—	—
Distal phalanges				
I	.150	.0144	34 × 102	.333
II	.116	.0111	30 × 100	.300
III	.125	.0120	28 × 100	.280
IV	.102	.0098	28 × 101	.278
V	.089	.0086	28 × 93	.301
Totals of distal phalanges	.582	.0559	—	—
Total of all bones	11.030	—	—	—

POLYDACTYLE.

	Grams Weight.	Percentage Weight.	Millimeters Measurement.	Percentage Index.
Ulna	2.829	.330	40 × 1015	.0394
Radius	2.188	.255	42 × 850	.0490
Carpals	.529	.061	—	—
Metacarpals				
A	.097	.011	20 × 157	.127
B	.261	.030	27 × 231	.113
C	.295	.034	26 × 260	.100
III	.292	.034	26 × 278	.094
IV	.291	.034	24 × 260	.091
V	.237	.027	25 × 212	.118
Totals of metacarpals	1.473	.170	—	—
Proximal phalanges				
A	.054	.0063	19 × 103	.184
B	.123	.0144	31 × 120	.258
C	.123	.0144	30 × 126	.238
III	.133	.0166	28 × 140	.200
IV	.123	.0144	27 × 132	.204
V	.090	.0105	28 × 101	.277
Totals of proximal phalanges	.646	.0766	—	—
Middle phalanges				
A	—	—	—	—
B	.073	.0085	25 × 85	.294
C	.071	.0083	23 × 83	.277
III	.078	.0091	18 × 101	.178
IV	.073	.0085	20 × 96	.208
V	.057	.0066	27 × 72	.375
Totals of middle phalanges	.352	.0410	—	—
Distal phalanges				
A	.092	.0107	24 × 79	.304
B	.110	.0128	25 × 99	.252
C	.105	.0123	28 × 102	.274
III	.096	.0112	28 × 99	.282
IV	.080	.0093	26 × 94	.276
V	.069	.0080	27 × 89	.315
Totals of distal phalanges	.552	.0643	—	—
Total of all bones	8.569	—	—	—

likewise, the metacarpal of digit *B* is more like metacarpal *A* than the metacarpal of digit *II* of the normal manus is like its pollex. Again, the metacarpal of digit *C* is more like its pollex metacarpal *A* than is the metacarpal of digit *III* of the normal manus like its pollex.

The same fact is also borne out by the comparison of the *indices*, which are mathematical expressions of the forms of the bones and can, therefore, be combined in the same way as the percentage weights.

That the two normal radial digits have given place to three, each of which partakes somewhat of the nature of the others, is shown by a consideration of the tissue systems, and in no way does this explanation meet with a decided contradiction. The evidence of the dorsal veins is negative and not contradictory.

I know of no case of polydactylism similar to the one here described. One which is somewhat similar is described by Windle (*Journ. of Anat.*, Vol. XXVI, 1891, p. 100), who in conclusion says: "The musculature shows that where there is an additional digit on the radial side, it and the digit next to the index both partake of the nature of thumbs and may be looked upon as the first and second digits of a hexadactylous manus."

In the case described in this paper, there is no reversion, and the anatomy of the polydactyle paw, as here worked out, has no bearing on either the "pre-pollex" or the "post-minimus" theories. The abnormality seems to result purely from a readjustment of parts. The only definite statement which can be made in regard to this case is that where normally two digits occur, three have here appeared, and that each of these three partakes more of the nature of the others than one of the two normal digits does of the other.

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